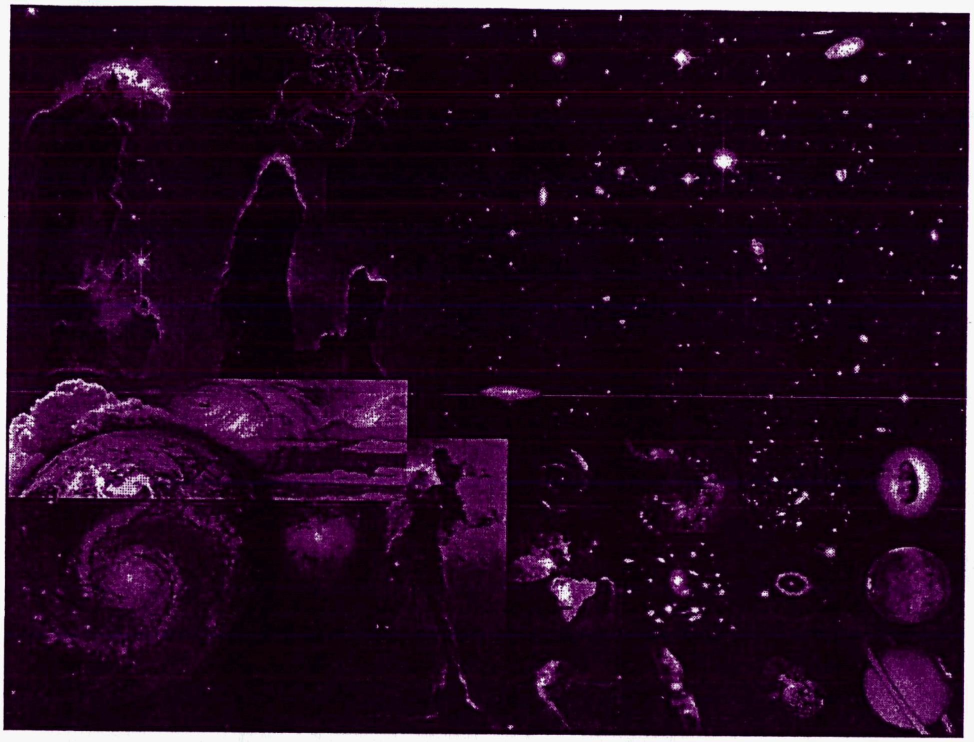


Engineering Technologies Overview
for NASA Space Exploration

Presentation to the
Scientific Research and Development Office
Polytechnic University of Puerto Rico

Irving Linares, Ph.D.
NASA GSFC

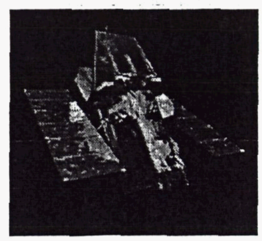
August 25, 2005

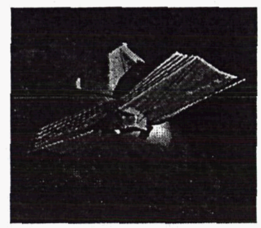
7

Agenda

- *Swift* Mission
  - Launched November 20, 2004
- *James Webb Space Telescope* (JWST)
  - A future 2011 mission
- NASA Engineering Technologies
- Conclusion
- Q & A

Swift





JWST

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Before Getting Started

- Have you ever thought about…
  - What are the NASA workforce statistics?
  - How are satellites built?
  - How could I use my engineering education in the space industry?
- *In this talk we will attempt to answer these basic questions.*

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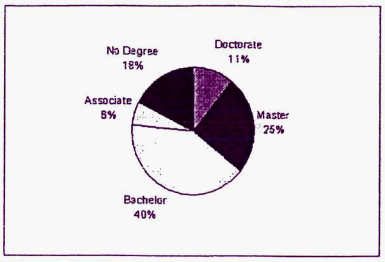
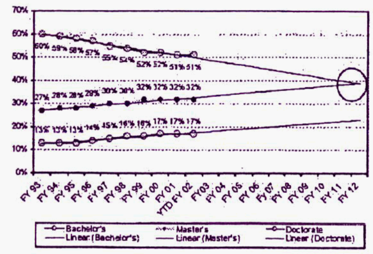
NASA Workforce





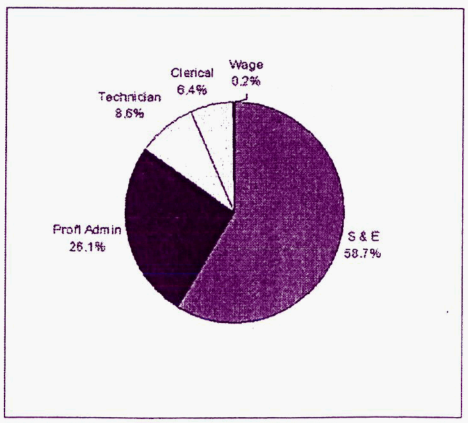
Education - Present

Currently 96%, 77%, and 73% of all Doctorate, Master's, and Bachelor's degrees, respectively, are held by Scientists and Engineers.

Education – Future

Given a linear trend over the past nine fiscal years, the percent of S&Es holding a Master's degree could potentially surpass the percent holding a Bachelor's degree in the next 10 years.

NASA Workforce



Occupations - Present

➢ Overall, professional positions constitute 85 percent of the NASA Workforce.

http://nasapeople.nasa.gov/workforce/education/present.htm

Swift Mission Science Goals

- *Swift* is a first-of-its-kind multiwavelength observatory dedicated to the study of gamma-ray bursts. The main mission objectives are:

  - Determine the origin of gamma-ray bursts (GRBs).

  - Classify gamma-ray bursts as well as search for new types.

  - Determine how the blastwave evolve and interacts with the surroundings.

  - Use gamma-ray bursts to study the early universe.

  - Perform a sensitive survey of the sky in the hard X-ray band.

- *Swift* is a NASA medium-sized explorer (MIDEX) mission that was developed by international collaboration.

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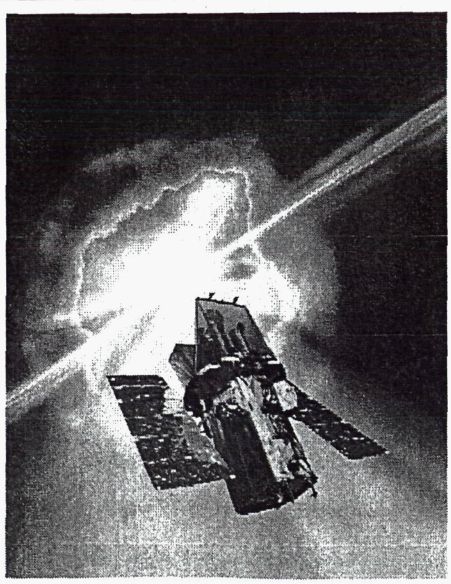
Artist's conception: Swift slewing towards a GRB.



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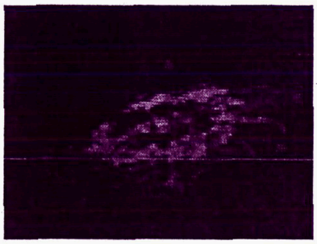
What is a GRB?

- A brief, but brilliant, burst of gamma-rays coming from a random point in the sky about once per day.
- Unimaginably huge explosions which signal the births of a black holes.
- Given the distance of the long bursts, they must put out about 10^53 ergs of energy.
- The Sun puts out about 10^33 ergs each second. It would take our Sun 880 billion years to put out the same energy as a GRB!
  - For perspective, our Sun will only live to be about 10 billion years, and our Universe is only about 12 billion years old.
- May be caused by:
  - Neutron Stars mergers
  - Hypernova
    - Collapse of a very dense star



Artist's conception: a Black Hole.

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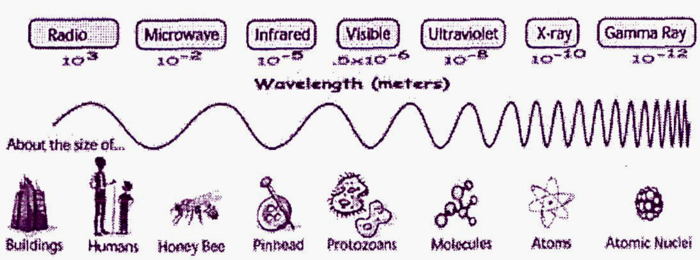
What are Gamma Rays?

- The entire electromagnetic spectrum stretches from very low-energy radio waves through microwaves, infrared radiation, visible light, ultraviolet light, X-rays, and finally to ***very high-energy*** gamma rays.
- The processes producing photons (single particles of electromagnetic radiation) of each type of radiation differ, as do their energy, but all of the different forms of radiation emitted are still just part of the electromagnetic spectrum's family.
- The only real difference between a gamma-ray photon and a visible light photon is the ***energy***. Gamma rays can have over a ***billion*** times the energy of the type of light visible to our eyes.



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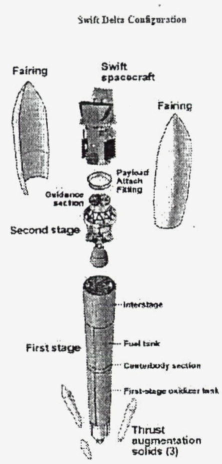
What are the Swift Mission Details?



Mission Details	
Orbit	LEO 600 km circular
Orbital Life	7 years
Inclination	20.6 degrees
Launch Date	November 20, 2004
Prime Mission Duration	2 years
Launcher	Delta II (7320)
Spacecraft Partner	Spectrum Astro
Peak Slew Rate	50 degrees in < 75 sec
Operations and Pointing	Autonomous
Uplink/Downlink	Dual Path • 2 kbps GRB alert downlink and uplink real-time using TDRSS DAS link • 2.25 Mbps data rate for store and dump using Malindi-ASI seven orbits per day

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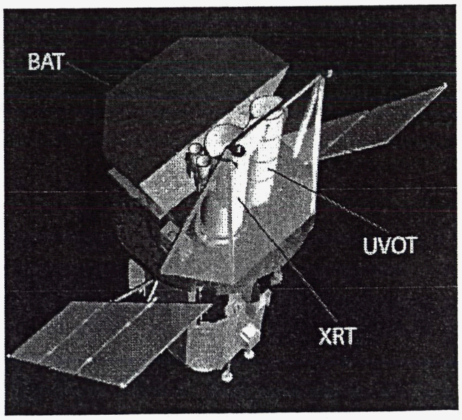
Swift Mission Instruments

- **Instruments**
  - X-ray Telescope (XRT)
  - Ultraviolet and Optical Telescope (UVOT)
  - Burst Alert Telescope (BAT)



http://swift.gsfc.nasa.gov/

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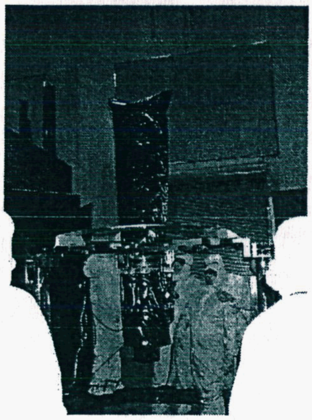
What are the UVOT specifications?



ULTRAVIOLET/OPTICAL TELESCOPE	
Telescope	Modified Ritchey-Chrétien
Aperture	30 cm diameter
F-number	12.7
Detector	Intensified CCD
Detector Operation	Photon Counting
Field of View	17 x 17 arcminutes
Detection Element	2048 x 2048 pixels
Telescope PSF	0.9 arcsec @ 350 nm
Location Accuracy	0.3 arcseconds
Wavelength Range	170 nm - 650 nm
Colors	6
Spectral Resolution (Grisms)	$\lambda/\Delta\lambda$ ~ 200 @ 400 nm
Sensitivity	B = 24 in white light in 1000 sec
Pixel Scale	0.48 arcseconds
Bright Limit	m_v = 7 mag

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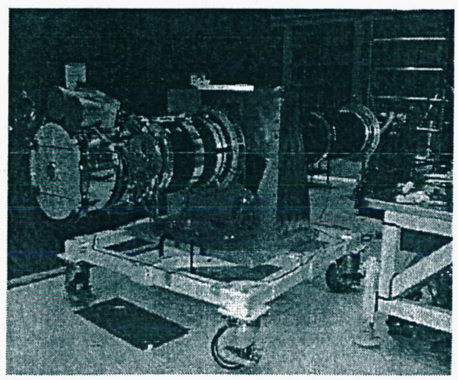
What are the XRT specifications?

X-RAY TELESCOPE	
Telescope	Wolter I
Detector	XMM EPIC CCD
Effective Area	135 cm^2 @ 1.5 keV
Detector Operation	Photon Counting, Integrated Imaging, & Rapid Timing
Field of View	23.6 x 23.6 arcminutes
Detection Element	600 x 600 pixels
Pixel Scale	2.36 arcsec/pixel
Telescope PSF	18 arcsec HPD @ 1.5 keV
Location Accuracy	3 - 5 arcseconds
Energy Range	0.2 - 10 keV
Sensitivity	2 x 10^{-14} ergs cm^{-2} s^{-1} in 10^4 sec



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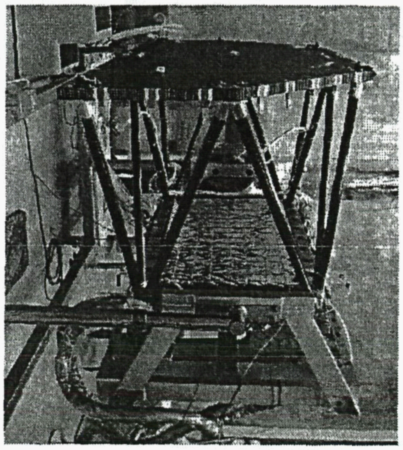
What are the BAT specifications?



Burst Alert Telescope	
Aperture	Coded Mask
Detecting Area	5200 cm^2
Detector	CdZnTe
Detector Operation	Photon Counting
Field of View	2.0 sr (partially coded)
Detection Elements	256 modules of 128 elements
Detector Size	4mm x 4mm x 2mm
Telescope PSF	17 arcminutes
Location Accuracy	1 - 4 arcminutes
Energy Range	15 - 150 keV
Burst Detection Rate	>100 bursts/year

Spectral Resolution:

7 keV FWHM averaged over all active detectors

12 keV FWHM max. for any detector

Sensitivity: 0.2 ph/cm2/sec

Timing Accuracy: 250 μs

Timing Resolution: 100 μs

Fluence BBOY: 195,000 counts/sec (entire array)

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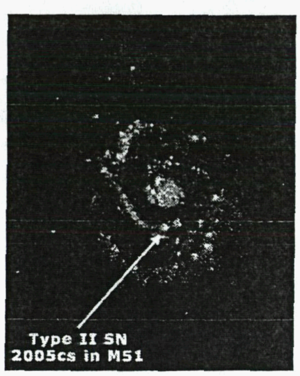
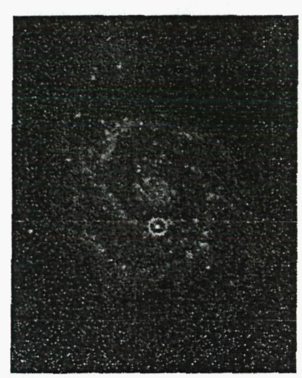
Swift Science Example - UVOT





UVOT images of **SN 2005cs**, a **Type II supernova** in the nearby galaxy M51. The image on the left is a false color image. In the ***ultra-violet*** image on the right, notice how the supernova is far brighter than the galaxy nucleus.

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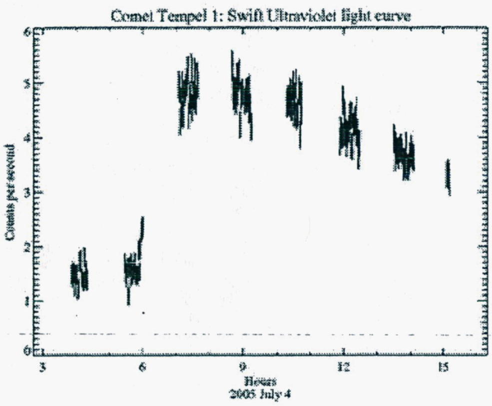
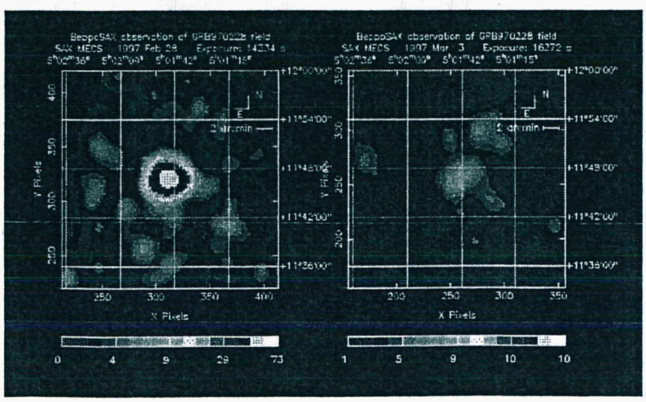
Swift Science Example - UVOT



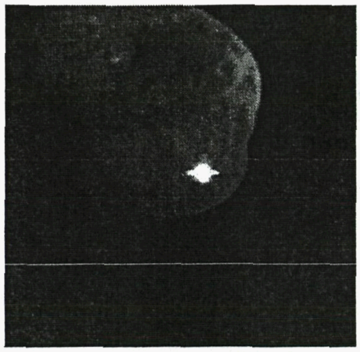
5 July 05: This chart shows the sudden brightening and gradual decline in ultraviolet light detected by Swift during the first 15 hours after the **Deep Impact** experiment on **Comet Tempel 1**. Gaps occur when Swift's 96-minute orbit takes it to the opposite side of the Earth from Comet Tempel.

Swift Science Example - XRT

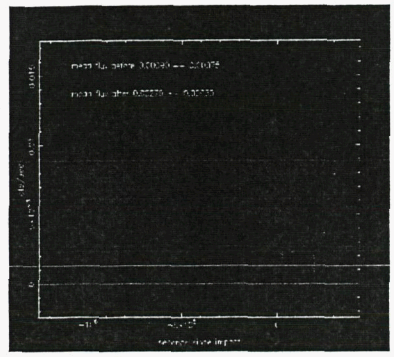


The images above show the X-Ray afterglow of **GRB 970228** made by BeppoSAX. The left panel, taken 8 hours after the burst, shows a strong X-ray afterglow. The right panel, taken 3 days later, shows how the afterglow has faded, but is still detectable.

Swift Science Example - XRT



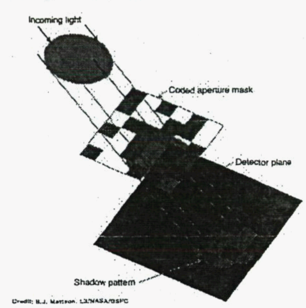
The image depicts the first moments after **Deep Impact's** probe interfaced with comet **Tempel 1**. *The illuminated debris is expanding* from the impact site. The roughhewn edges at the top and bottom of the flash are a result of light given off at impact saturating some of the *pixels in the camera's imager. The pixels* "bleed" excess electronic charge onto adjacent pixels in the same column.



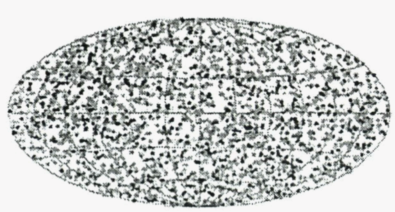
7 July 05: Light curve of Swift's **X-ray** detections from Comet Tempel 1 showing count rate (blue - before impact, red = after impact) The dramatic increase begins about 3-1/2 days after impact (300,000 seconds).

Swift Science Example - BAT

- Detect > 300 GRB/year
- Detect short (<0.1 s) and long GRB (>100 s)
- How is the GRB detected?

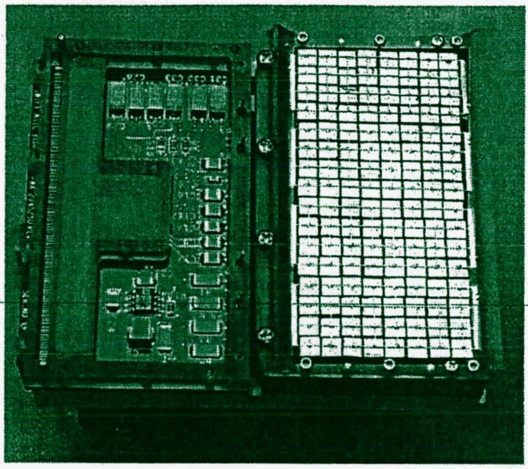


GRB shadow pattern.



GRBs detected by BATSE. Notice they are distributed all over the sky.

How was BAT built?



CZT Detector Module

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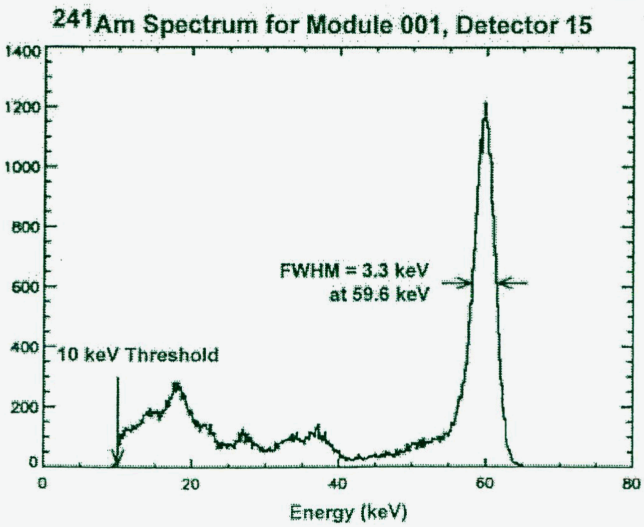
CZT Response



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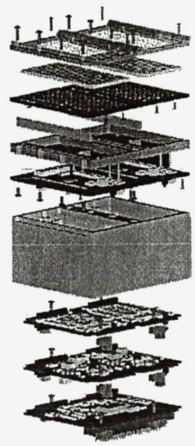
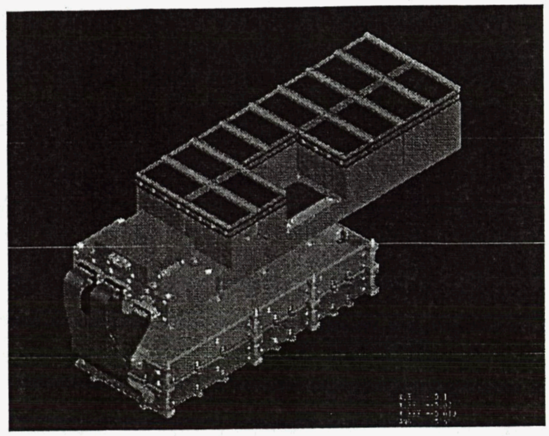
BAT *Blocks*



Detector Module (DM)



BAT Blocks

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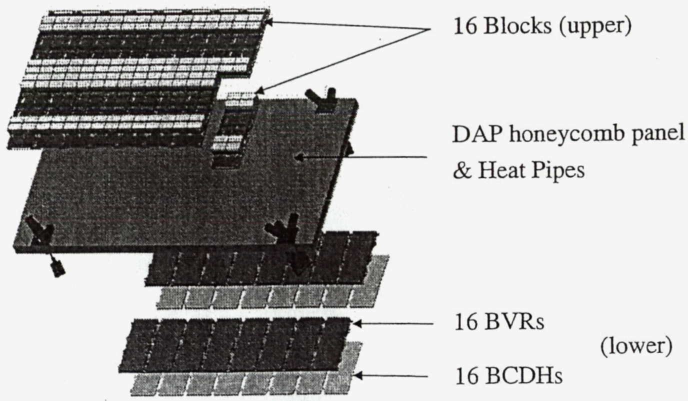
BAT Detector Array



Detector Array (32768 detectors)

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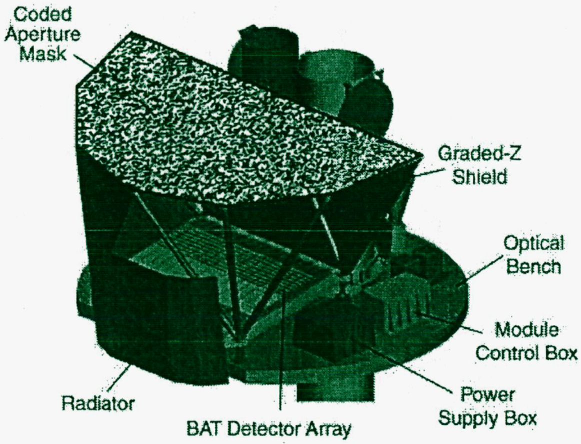
BAT Instrument



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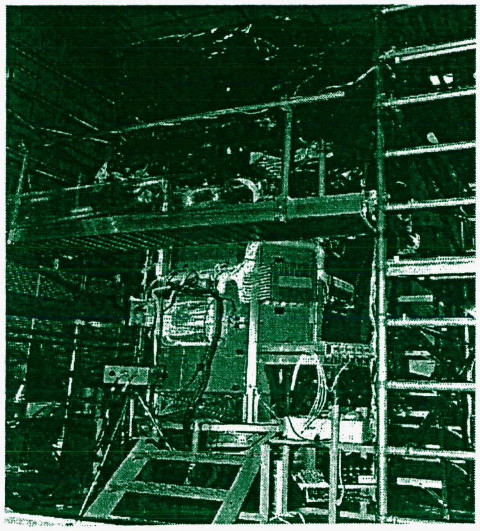
Swift I&T at GSFC



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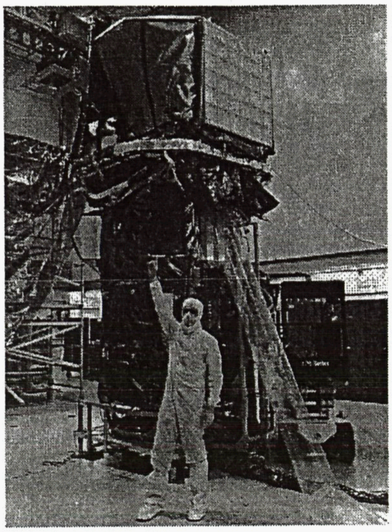
Real-Size Swift



Mass: 1470 kg

Power: 1040 W

Dimensions (deployed):
18.5' H x 17.8' W
(5.64m H x 5.4m W)

Lauch Vehicle: Delta II (7320)

Orbit: 20° inclination, 600 km altitude

Cost: $ 250M

http://heasarc.gsfc.nasa.gov/docs/swift/news/2004/swift_presskit.pdf

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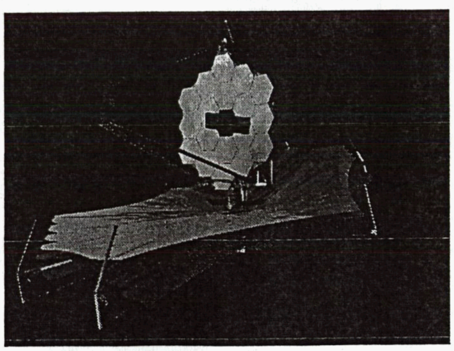
James Webb Space Telescope



- JWST development is led by NASA's Goddard Space Flight Center.
- The JWST is an international collaboration among NASA, ESA, and CSA.

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JWST Science Goals

- The James Webb Space Telescope (JWST) is an orbiting *infrared* observatory that will take the place of the Hubble Space Telescope at the end of this decade.
- It will study the Universe at the important but previously unobserved epoch of galaxy formation.
- It will peer through dust to witness the birth of stars and planetary systems similar to our own.
- Using JWST, scientists hope to get a better understanding of the intriguing dark matter problem.
- The JWST is also a key element in NASA's Origins Program.

http://jwst.gsfc.nasa.gov

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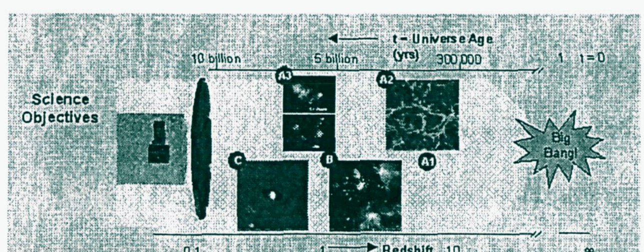
JWST Science Goals



(A) **Formation of galaxies**, from the first luminous massive condensations of material(A1) through the reionization(A2) of the Universe, to the assembly of galaxies and clusters and the development of morphological types (A3)

(B) **Formation of stars and brown dwarfs**, from twice the mass of Jupiter to the mass of the sun (1000 M_J) (B). We will probe the collapse of pre-stellar cores and test current ideas that the collapse is influenced by the local Jeans mass (near 1 $M_\odot$) and by opacity-limited fragmentation (near 10 M_J)

(C) **Planetary systems from birth to maturity.** We will use coronagraphy to image and obtain spectra of debris disks(C) and compare their properties with those of our own counterpart, the Kuiper Belt. We will image and obtain spectra of massive giant planets around nearby stars, to determine their relation to debris disk structure and their atmospheric properties

http://hubblesite.org/newscenter/

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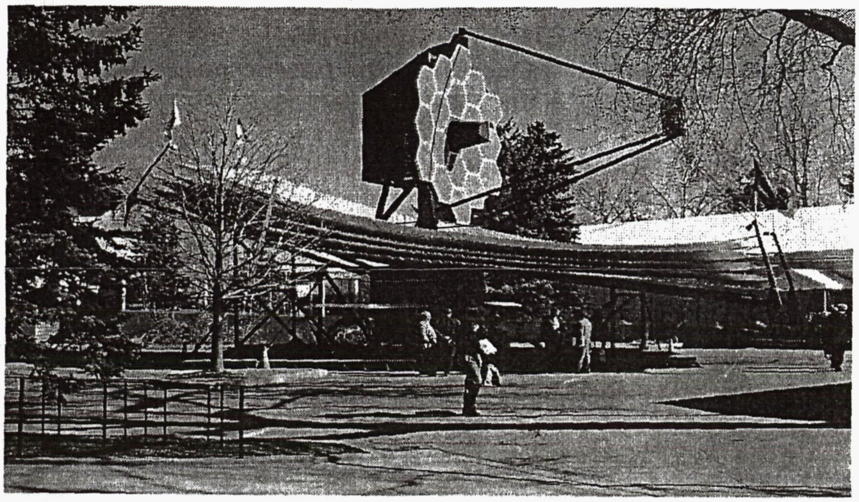
JWST Observatory Mockup



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JWST Mission Goals

- Determine the shape of the Universe.
- Explain galaxy evolution
- Understand the birth and formation of stars
- Determine how planetary systems form and interact.
- Determine how the Universe built up its present chemical/elemental composition.
- Probe the nature and abundance of Dark Matter.

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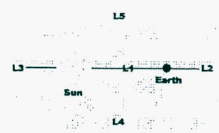
JWST Fast Facts

- Proposed Launch Date: August 2011
- Proposed Launch Vehicle: Atlas V, Delta IV, or Ariane 5.
- Mission Duration: 5 - 10 years
- Total payload mass: Approx 6200 kg, including observatory, on-orbit consumables and launch vehicle adaptor.
- Diameter of primary Mirror: ~6.5 m (21.3 ft)
- Clear aperture of primary Mirror: 25 m 2
- Primary mirror material: beryllium
- Mass of primary mirror: about one-third as much as Hubble's
- Focal length: TBD
- Number of primary mirror segments: 18
- Optical resolution: ~0.1 arc-seconds
- Wavelength coverage: 0.6 - 28 microns
- Size of sun shield: ~22 m x 10 m (72 ft x 33 ft)
- Orbit: 1.5 million km from Earth at L2 Point
- Operating Temperature: under 50 K (-370 deg;F)



The five Lagrangian points of the Earth-Sun system.

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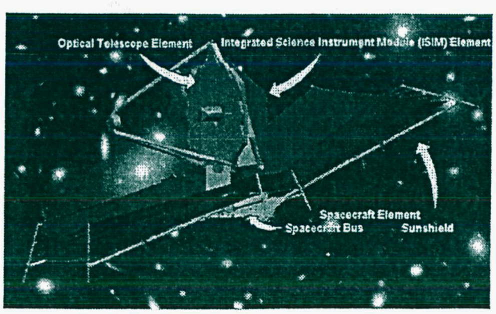
JWST Mission

The JWST Observatory consists of three elements:

- Optical Telescope Element (OTE)
- Spacecraft Element (s/c bus and sunshield)
- The **Integrated Science Instrument Module** (ISIM)
  - Near Infrared Camera (**NIRCam**)
  - Mid Infrared Instrument (**MIRI**)
  - Fine Guidance Sensor (**FGS**)
  - Near Infrared Spectrograph (**NIRSpec**)



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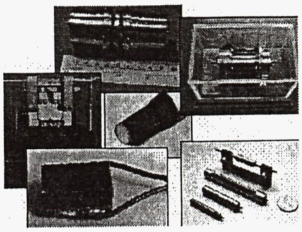
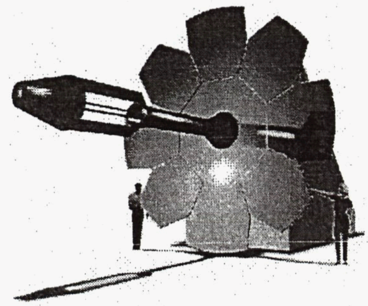
OTE



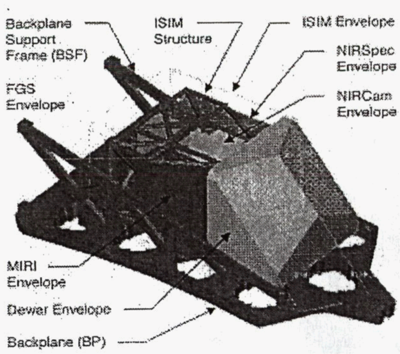
Cryogenic Actuators
The primary mirror for JWST will not have the luxury of being massive and retaining its perfect optical shape through material stiffness. The quality of the reflective surface will be computer controled via actuators which can adjust the shape of the mirror to give high quality, sharp images. These actuators will need to work at the extremely cold temperatures that JWST is expected to operate at (~30-100 Kelvin). Mirror actuation is one aspect of microdynamics that JWST must address.

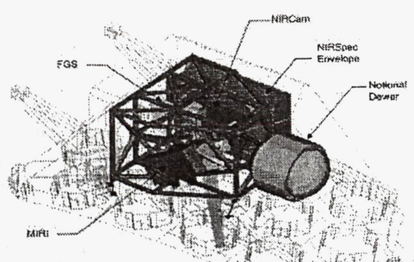


Scale drawing of 6.5-meter JWST primary mirror.

http://jwst.gsfc.nasa.gov/OTE/index.html

ISIM

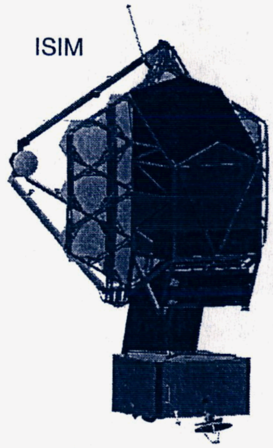


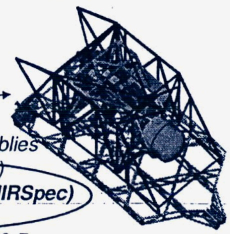


ISIM

ISIM is:
- **Science Instruments**
- **Associated Infrastructure: Structure, C&DH, & FSW**

ISIM





Region 1
Science Instrument Optics Assemblies
~~Near Infrared Camera (NIRCam)~~
Near Infrared Spectrograph (NIRSpec)
- including MSA
Mid Infrared Instrument (MIRI), & Dewar
Fine Guidance Sensor and Tunable Filter (FGS/TF)
ISIM Structure
Radiators and support structure (NGST-supplied)

Region 2
Focal Plane Electronics (FPE)
Instrument Control Electronics (ICE, ***MCE****)*

Region 3
ISIM Command & Data Handling (C&DH) Electronics

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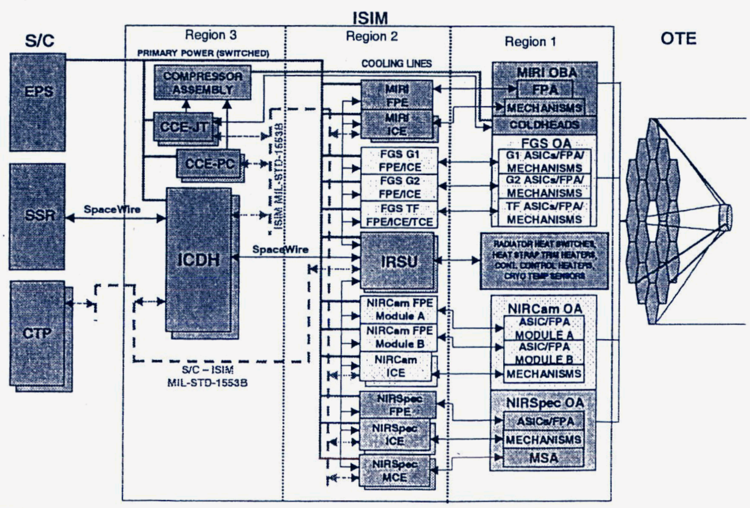
ISIM Electrical Architecture



ISIM Block Diagram.

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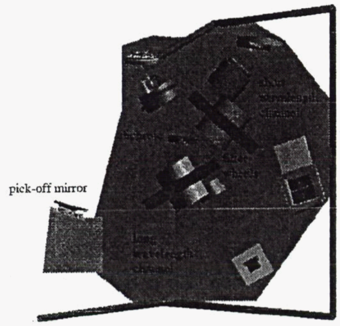
NIRCam

- The Near Infrared Camera (NIRCam) will be the *primary* JWST imager in the wavelength range of 0.6 to 5 microns.
- The NIRCam is required by many of the core science goals of JWST, including:
  - detection of the early phases of star and **galaxy formation**, such as the first precursors to today's globular clusters;
  - **morphology and colors of galaxies** at very high redshift in rest-frame optical wavelengths;
  - detection of and light curves of distant supernovae;
  - **mapping dark matter** via gravitational lensing;
  - the study of stellar populations in nearby galaxies.

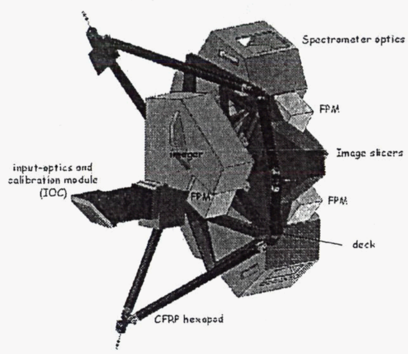


Optical Layout of one of two NIRCam Imaging Modules

44

Mid Infrared Instrument (MIRI)

- MIRI will provide the JWST with imaging and spectroscopy at wavelengths from 5 through 27 microns.
- It complements the two other JWST instruments, NIRCam and NIRSpec, which work from 0.6 to 5 microns.



http://ircamera.as.arizona.edu/MIRI/page2.htm

45

Infrared Light

At their normal body temperature (98.6 degrees Fahrenheit), humans radiate most strongly in the MIRI spectral range, at a wavelength of about 10 microns. This image at 10 microns (courtesy of the Infrared Processing and Analysis Center at CalTech), shows a man holding up a lighted match!

http://ircamera.as.arizona.edu/MIRI/why_mid.htm

46

FGS

- The Fine Guidance Sensor (FGS) will provide high-precision pointing error signals to the observatory Attitude Control Subsystem (ACS) to enable stable pointing at the *milli-arcsecond* level.
- The FGS will have sufficient sensitivity and a large enough field of view to assure that an appropriate guide star is available with 95% probability at any point in the sky.
- The Fine Guidance Sensor (FGS) will be supplied by the Canadian Space Agency (CSA).

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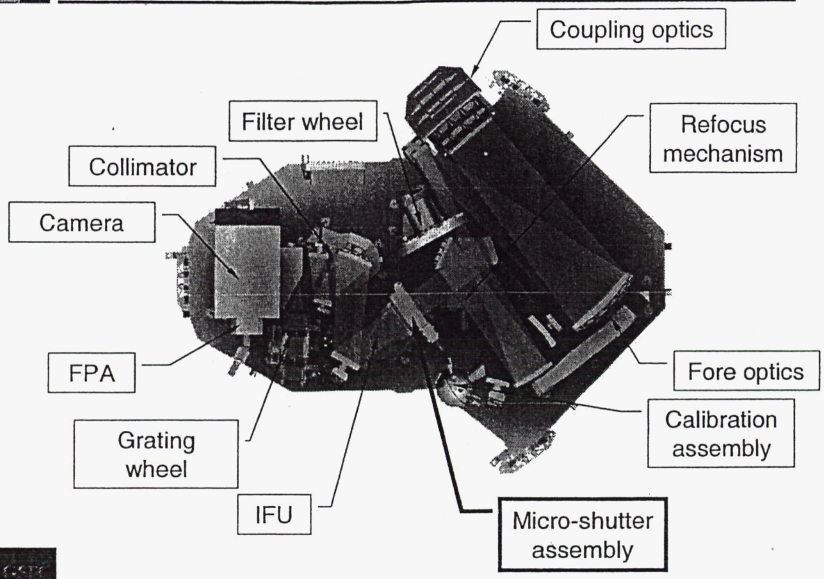
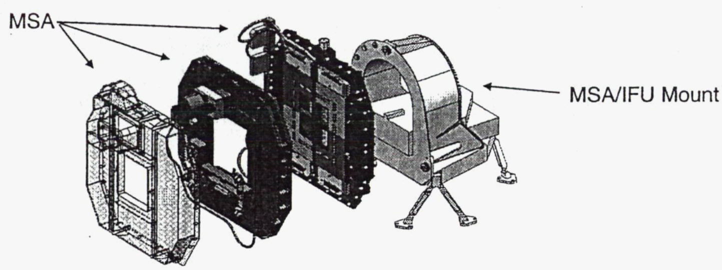
NIRSpec Instrument Layout

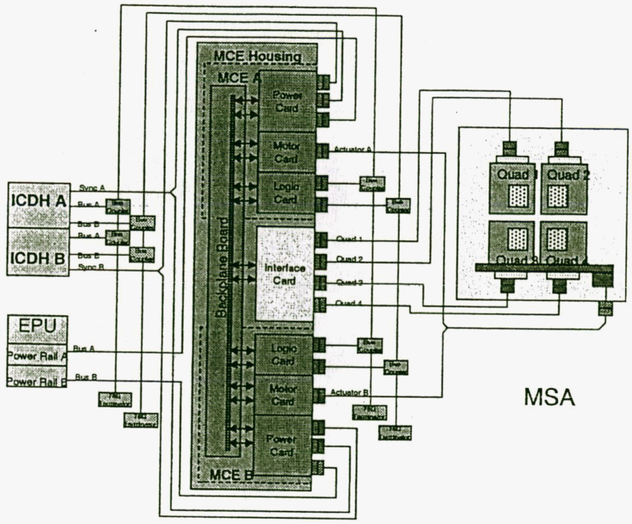


NIRSpec MSA Layout & Interfaces



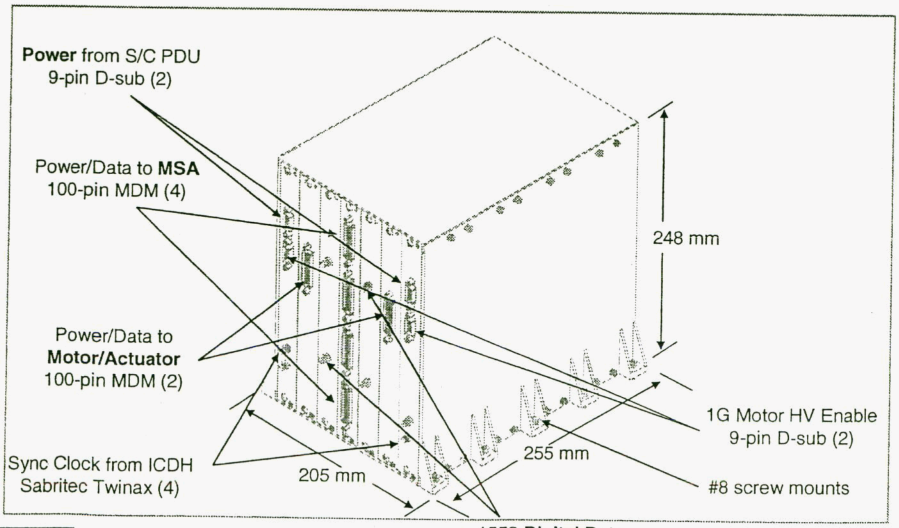
- Interface Descriptions
  - MSA
    - Mechanical interfaces to MSA/IFU mount provided by ESA.
    - Additional interface with ESA on IFU aperture block on moving magnet bracket.
    - Electrical interface of MSA to cables internal to NIRSpec Connector Panel.
    - Thermal interface through struts.
  - MCE
    - Mechanical/thermal interface to ISIM IEC
    - Electrical Interface to ISIM ICDH Computer.

Micro-shutter Control Electronics (MCE) In Context



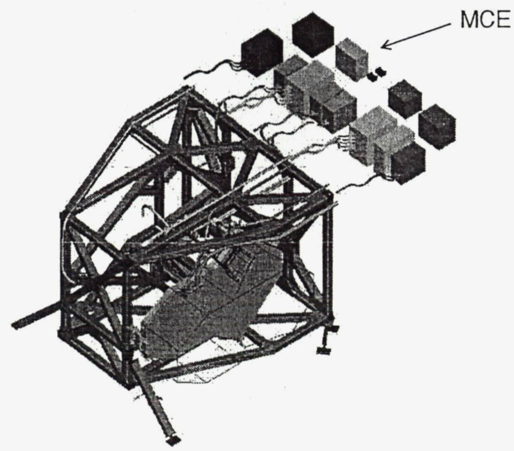
(MSS = MCE + harness + MSA) ↔ NIRSpec ↔ ISIM ↔ JWST

MCE Assembled View



1553 **Digital Data**
Input/Output from ICDH
Sabritec Triax (4)

MCE Location within ISIM



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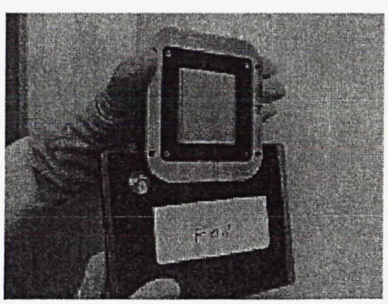
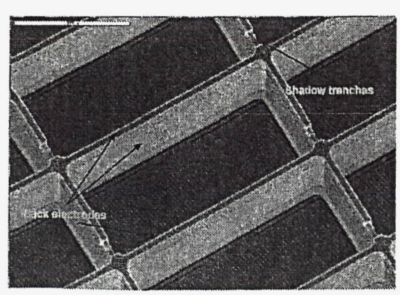
Microshutters



- One quadrant
  - a 171 x 365 element array.
  - or 62415 microshutters
- Full Array: 249660 microshutters



SEM photo showing 100μ x 200μ shutters.

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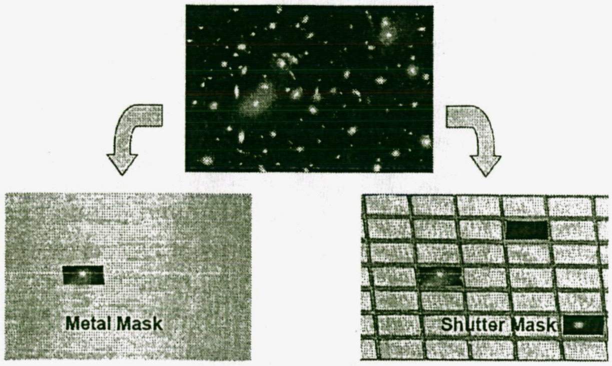
Microshutters Science Promise



- A controllable and reconfigurable aperture-mask allows optical transmission to a spectrograph.
- It will replace traditional single slits that are not reconfigurable.
- **Net result & Science promise:** *Hundreds* of simultaneous independent observations!

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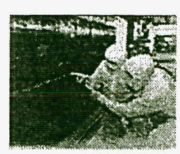
NASA Engineering Technologies



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NASA Engineering Technologies

- Instrument Management
- Systems Engineering
- Detectors
- Mechanical Engineering
- Electrical/Electronics
- Electromechanical
- Optics
- Thermal
- Flight Software
- Ground Control Software
- Contamination Control
- Instrument Development
- Integration & Test
- Electrical and Mechanical Ground Support Equipment
- Financial & Resource Management
- Configuration Management
- Planning & Scheduling
- Many others...

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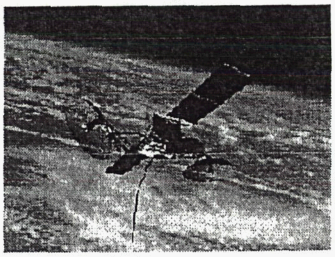
Instrument Management

- Description
  - Responsible for the overall design, development, and I&T of a space flight instrument or spacecraft.
  - Interfaces with scientists, engineers, management, contractors, universities, vendors, and other Government agencies to ensure that the deliverable complies with its specifications.
- Main responsibilities
  - Manages budget, personnel, resources, and schedule to ensure a timely and within-cost product deliverable.
  - Negotiates interdisciplinary changes as needed.
- Required Education
  - BS/MS in EE, ME, aerospace or other engineering degree. MBA or equivalent training useful and desirable.
- Typical projects
  - Planetary probes, satellites, optical or ultraviolet telescopes, Gamma-ray or X-ray telescopes, IR telescopes.
  - Examples: COBE, TRMM , XTE, EUVE, MIDEX, HST, NGST, LANDSAT7, POES, GOES, TDRS, EO-1, TOMS, GLAST



TDRSs offers S and Ku-band Single Access (SA) services, and Multiple Access (MA) services.

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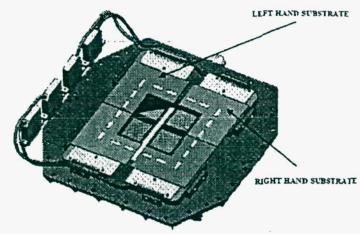
Systems Engineering

- Description
  - Ensures that the spacecraft or instrument operates and complies with all its requirements.
  - Interfaces with scientists, engineers, management, contractors, universities, vendors, and other Government agencies to ensure that the deliverable complies with its specifications.
- Main responsibilities
  - Enforces Configuration Control.
  - Oversees "Verification Matrix" compliance.
  - Defines, controls, and manages interfaces among ***interdisciplinary*** areas of engineering.
    - Interfaces include: mechanical, electrical, electronics, thermal, software, space radiation, optics, EM/RF, detectors, etc.
  - Documents requirements traceability.
- Required Education
  - BSEE, BSME, BS in aerospace engineering, advanced MS degree desirable.
- Typical projects
  - Planetary probes, satellites, optical or ultraviolet telescopes, Gamma-ray or X-ray telescopes, IR telescopes.
  - Command & Data Handling interfaces.
  - Thermal, mechanical, or electromechanical interfaces.

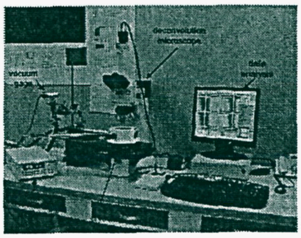
Fourth Quadrant Integrated



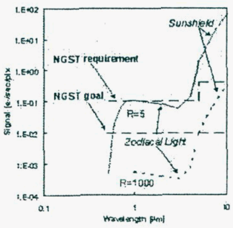
MSA showing electrical and mechanical Interfaces.

Detector Engineering

- Description
  - Designs, develops, and/or procure detectors such as CCDs, NIR detectors, visible light detectors, UV detectors, and sensor chip arrays (SCAs.)
  - Designs, develops, and/or procures analog front-end electronics to serve as readout devices for ADC conversion.
- Main responsibilities
  - Provide flight-qualified detectors to science instruments.
  - Interface with scientists, engineers, management, etc.
- Required Education
  - BSEE, BSME, physicist. Advanced MS or Ph.D. desirable.
- Typical projects
  - JWST detectors:
    - NIR: HgCd Te or InSb
    - MIR: Si:As IBC (impurity band conduction).
  - Swift detectors:
    - CdZnTe (CZT)



Microshutter Bowing testing:
cryogenic deconvolution microscope.

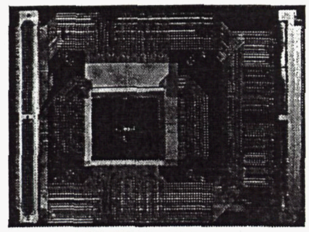


JWST Detector Development

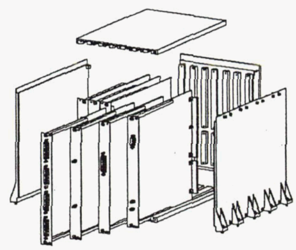
The JWST must have great sensitivity to detect the first light in the universe and learn how galaxies first formed. This goal requires that JWST detect sources as **faint as magnitude 33** - which implies less than one photon per second at the detector! For this, JWST must employ detectors more sensitive than any flown on previous missions.

Mechanical Engineering

- Description
  - Provides multi-disciplinary capabilities and technology development to design, analyze, fabricate, integrate, test, and launch advanced scientific instruments and support platforms for a variety of ground-based, suborbital, and orbital space and Earth science missions.
- Main responsibilities
  - Materials Engineering
  - Mechanical Systems Analysis & Simulation
  - Electro-Mechanical Systems
  - Thermal Engineering
  - Contamination & Coatings Engineering
  - Advanced Manufacturing
  - Mechanical Systems Integration
  - Environmental Test Engineering and Integration
- Required Education
  - BSME. MS desirable.
- Typical projects
  - Design of electromechanical actuators
  - Sinusoidal & random vibration testing
  - Thermal Vaccum testing
  - Spacecraft mechanical platform design
  - Optical, IR, or UV telescope alignment
  - Piezoelectric characterization
  - Computer Numerically Controlled (CNC) manufacturing
  - Pyrotechnics
  - Printed Circuit Board layout



HV-584 test board.

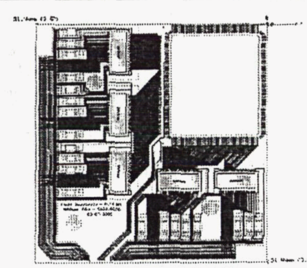


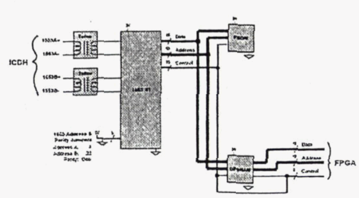
Exploded view of the MCE.

60

Electrical/Electronics Engineering

- Description
  - Encompasses the design, manufacturing, and I&T of electronic circuits, power systems, network systems, detector electronics, digital electronics, RF and microwave electronics, etc.
  - Interfaces with scientists, engineers, management, contractors, universities, vendors, and other Government agencies to ensure that the deliverable complies with its specifications.
- Main responsibilities
  - Flight Data Systems
  - Command & Data Handling (C&DH)
  - Microelectronics & Signal Processing
  - EE parts packaging
  - AC/DC power systems
  - Electrical/Fiber Optic interface harnessing
  - Microwaves & Communications





- Required Education
  - BSEE, MSEE, BS CS/CE, MS CS/CE
- Typical projects
  - VLSI/HDL design
  - PCB layout
  - ASIC/FPGA design
  - OP-AMP based design for analog FEE
  - DC-DC converter based power systems
  - µP based design
  - TCP/IP based network design
  - GSE design
  - C/C++/ASM H/W driver development

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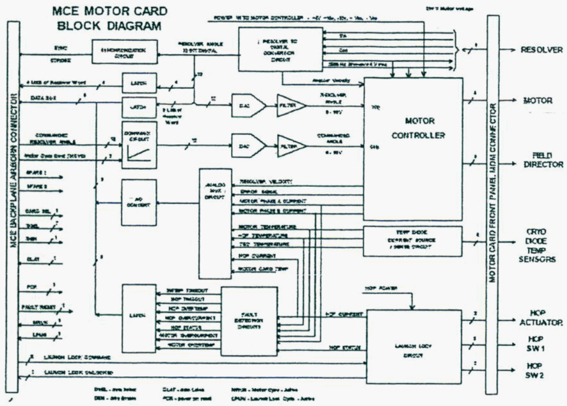
Electromechanical Engineering

- Description
  - Design, development, manufacturing, and I&T of space flight qualified electromechanical devices such as motors, actuators, selenoids, torque/speed conversion gear, position sensors, etc.
- Main responsibilities
  - Electro-Mechanical Systems
  - Motor controller electronics
    - Stepper motors
    - AC/DC motors
  - Actuator electronics
  - Motor commutation electronics
  - CAD/CAE design of electromechanical devices
- Required Education
  - BSME. MS desirable.



- Typical projects
  - Design of electromechanical actuators
  - Piezoelectric transducers
  - Closed-loop PID electromechanical controllers
  - ADC of mechanical/physical measurements
    - Displacement, velocity, acceleration, temperature
  - Time/frequency DFT analysis of electromechanical devices
  - Harness heat transfer modeling
    - Joule (I^2R) and parasitic heating (dT/dI) models

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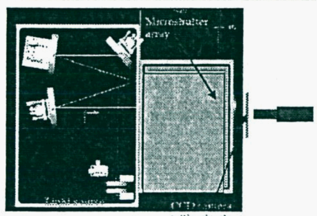
Optics

- Description
  - Optical engineers design and develop advanced optics for IR, UV, and visible spectrum telescopes.
- Main responsibilities
  - Support scientists, engineers, and other customers in modeling, developing, and manufacturing of optical systems.
- Required Education
  - BS physics, astronomy, astrophysics, BSME. Advanced MS or Ph.D. desirable.
- Typical projects
  - Fizeau Interferometer/Sparse Aperture Telescope missions
    - Utilize 7-20 separate articulated apertures automatically controlled
  - Instantaneous Acquisition Phase Shifting Interferometry for JWST
    - Removes vibrations
  - Optical Modeling and Characterization
    - Coronagraphic telescope
  - Formation Flying interferometry



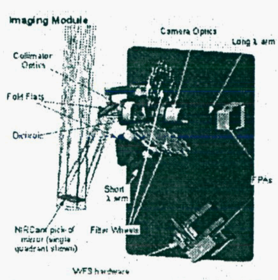


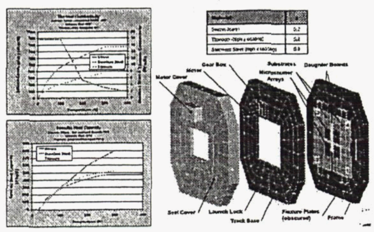
Figure 4: Layout of a NIRCam imaging module. The tunable filter modules are similar.

http://www.astronautical.org/Presentations/Goddard05/3Goddard05_Fienberg.pdf

63

Thermal Engineering

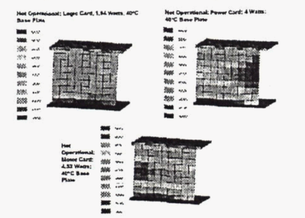
- Description
  - Responsible for developing and applying technology to meet the thermal and contamination control requirements of Goddard-managed spacecraft and space-borne scientific instruments.
- Main responsibilities
  - **Develop and integrate thermal control systems** for spacecraft and instruments.
  - Provide **contamination control** design, analysis, and protection of critical instrument and spacecraft components and surfaces.
  - Develop and assess **thermal and contamination software packages.**
  - **Provide technical oversight**, evaluation, consultation, and support to flight projects, instrument developers, design review teams, failure analysis teams, technical evaluation panels, and source evaluation boards.



MSA Thermal Math Model

http://mscweb.gsfc.nasa.gov/545web/Default.html

Preliminary MCE Thermal Analysis Results



- *Required Education*
  - BSME, MSME desirable.
- Typical projects
  - Satellite cooling systems
    - Swift passive cooling using Loop Heat Pipes
  - Execution of thermal control systems on both Shuttle and EVLs
  - Thermal Analysis for GSFC missions.
  - Fabrication of spacecraft Multi-Layer Insulation (MLI)
  - Molecular and particulate contamination
    - Molecular Kinetics *(MOLEKIT) Facility*
    - Bidirectional Reflectance Distribution Function (BRDF) Facility
  - Installation of thermal hardware
    - Heaters, thermistors, TCs, etc.

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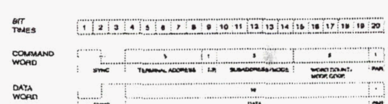
Flight Software

- Description
  - A **science observing command plan**, which will typically cover a period of one day to a few days, is loaded from the ground into flight memory.
  - FSW coordinates vehicle pointing, spacecraft and science instrument commanding, data handling, and ground communications, while simultaneously assuring that the flight hardware is being operated in a completely safe and healthy manner.
- Main responsibilities
  - Time management
  - Command Management
  - Attitude Determination & Control
  - Orbit Determination
  - Orbit Maintenance
  - Mode Management
  - Telemetry Monitor
  - Data Storage
  - Flight Electronics Diagnostics
  - FSW Maintenance
  - Anomaly/Failure Detection
  - Anomaly/Failure Response



- ***1553 Message***
  - one 1553 **Command Word**, written by 1553 Bus Controller
  - 0-32 1553 **Data Words**, written or read by 1553 Bus Controller

MIL-STD-1553B

- Required Education
  - BSEE, MSEE, BS CS/CE, MS CS/CE, BS/MS in math, physics, Ph.D. desirable.
- Typical projects
  - *CASSINI-HUYGENS*
  - EO-1 (Earth Observing-1)
  - Fast Auroral Snapshot Explorer (FAST)
  - POES
  - Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX)
  - Tropical Rainfall Measuring Mission (TRMM)

http://fsw.gsfc.nasa.gov/default.htm

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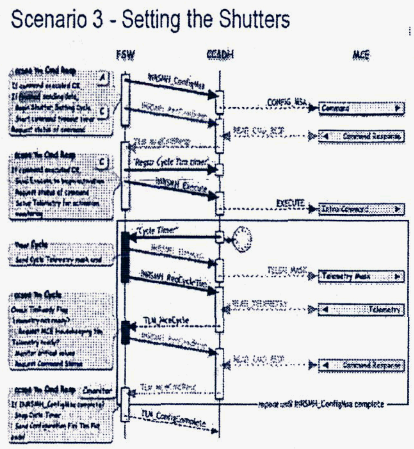
Ground Control Software

- Description
  - Formats/dissasembles command packets in accordance with CCSDS or equivalent standards for uplink/downlink to orbiting spacecraft or deep-space probes.
  - Designs, integrates, and tests ground control computer systems for spacecraft command, communications, and control (C^3)
- Main responsibilities
  - The software engineer writes the software, selects/modifies an applicable mostly real-time operating systems for s/c C^3
- Required Education
  - BSEE, MSEE, BS CS/CE, MS CS/CE, BS/MS in math, physics, Ph.D. desirable.
- Typical projects
  - Star trackers for Shuttle and unmmaned s/c, e.g., NEAR, XTE
  - Solar wind data processor, e.g., ACE
  - Magnetospheric Imager, e.g., Cassini
  - Extreme Ultraviolet (EUV) instrument controller
  - Implementation of Mission Operations Control Centers (MOCCs), e.g., LANDSAT



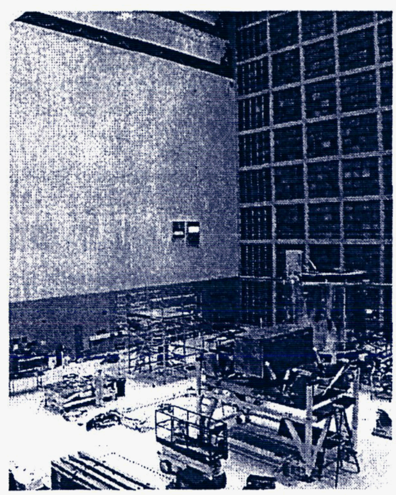
http://forth.gsfc.nasa.gov/

66

Contamination Control

- Description
  - Contamination Control Engineering improves system performance by minimizing contaminants that adversely affect optics, sensors, and space systems.
- Main responsibilities
  - Modeling of contamination environments and their impact on instruments or spacecraft.
  - Provides facilities and procedures to reduce contamination during manufacture, integration, test, transportation, and launch activities.
  - Designs and develops sensors and contamination control devices (molecular adsobers, CO2 cleaning, etc.)
  - Develops On-orbit contamination control operations and methodologies.
  - Selects materials and coatings for operations in the space environment
- Required Education
  - BSME, BSChE, BS in Physics
- Typical projects
  - Earth Observing (EOS) series
  - Far Ultraviolet Spectroscopic Explorer (FUSE)
  - Hubble Space Telescope (HST)
  - Microwave Anisotropy Probe (MAP))
  - Solar Heliospheric Observatory (SOHO)
  - Total Ozone Mapping Spectrometer (TOMS)
  - Transition Region and Coronal Explorer (TRACE)
  - Tropical Rainfall Measurement Mission (TRMM)
  - Vegetation Canopy Lidar (VCL)
  - Wide-Field Infrared Explorer (WIRE)

http://sm3a.gsfc.nasa.gov/ssdif.html



SSDIF clean room at GSFC. It is 1,000 times cleaner than a hospital operating room. Observe the technician in relationship to the building height.

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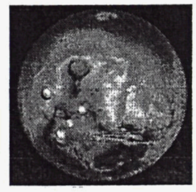
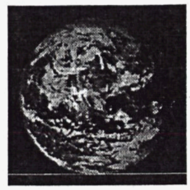
Instrument Development

- Description
  - Design, fabrication, integration, calibration, and test of instruments for studying the Earth.
  - Also engaged in instrument design to study other terrestrial planets like Mars and Mercury.
  - These instruments cover the whole EM spectrum.
- Main responsibilities
  - Interface with scientists, engineers, management, etc., in a highly technical environment to ensure compliance with all remote sensing mission requirements.
  - Advise management in proposal generation.
  - Oversee contractor support.
- Required Education
  - BS/MS/Ph.D. in EE, CE, CS, ME, aerospace engineering, physics, astrophysics, metereology, chemistry, materials, solid-state physics.
- Typical projects
  - LASER altimeters
  - Very Long Baseline Interferometry (VLBI)
  - Radiomentric calibration
  - Solar UV Irradiance
  - Future spectrometer on a chip



MOLA is a laser altimeter that sent back data on Mars topography.



Geodesy applied mathematics uses observations and measurements to determine the exact positions of points on the earth's surface.

Landsat-7 image of Washington, DC. showing vegetation, urbanization, and land use.

http://ssbuv.gsfc.nasa.gov/

http://ltp-education.gsfc.nasa.gov/about.html

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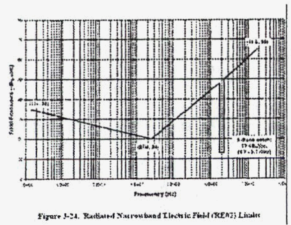
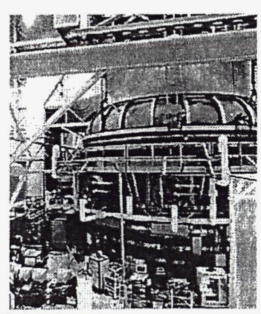
Integration & Test

- Description
  - The process by which all flight hardware (electronics, mechanical systems, thermal systems etc.) is assembled and where subsequent verification of proper function and suitability for intended purpose is demonstrated and verified. This includes both functional and environmental testing.
- Main responsibilities
  - Electrotromagnetic Interference (EMI) Testing
  - Electromagnetic Compatibility (EMC) and Magnetics testing.
  - Susceptibility tests form 30 Hz to 400 MHz for signal injection, and 10 kHz to 40 GHz for signal radiation.
  - Determination of mass properties and modal characteristics of payloads.
  - Vibration Testing
  - Perform simulated space and Thermal Cycle testing of Earth orbit and deep space flight hardware.
  - Acoustics Testing
- Required Education
  - BS/MS in ME, EE, CE.
- Typical projects
  - EOS, FUSE, HST, Landsat
  - MAP, SOHO, TOMS, TRACE, TRMM
  - VCL, WIRE, Swift, GLAST





Very large Space Environment Simulation (SES) test chamber capable of achieving ultra low pressure <13.3 μPa (10^{-7} torr).

http://eed.gsfc.nasa.gov/568/568cando.html

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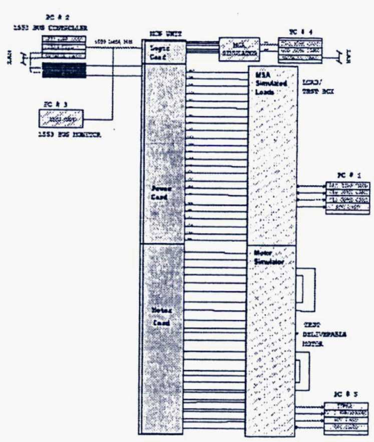
EGSE & MGSE

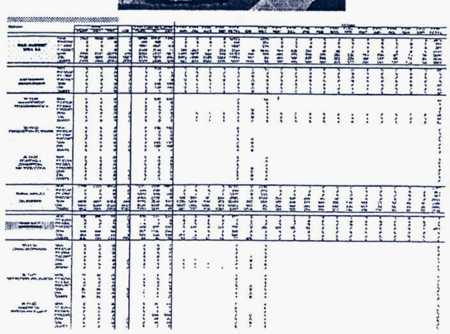
- Description
  - Replicates space flight environment on the ground.
  - Electrical Ground Support Equipment (EGSE) includes computers, I/O cards, S/C computer control software, graphical user interface (GUI) development, science algorithm implementation, cables and harnesses, computer networks, and the peripherals necessary to test a flight system or subsystem prior to launch.
  - Mechanical Ground Support Equipment (MGSE) includes the thermal, structural, instrumentation, pneumatic, hydraulic, and electromechanical devices necessary to test a flight system or subsystem.
- Main responsibilities
  - Design, procure, fabricate, integrate and test EGSE and/or MGSE for a flight project.
  - Maintain the software, electronics, structures, and electromechanical subsystems of the GSE.
  - Support the I&T manager.
- Required Education
  - BS in EE, CE, CS, aerospace, ME & other engineering. MS helpful.
- Typical projects
  - All past and current flight missions including: EOS, FUSE, HST, Landsat, Swift, JWST, etc.

MCE Unit Level Testing



Financial & Resource Management

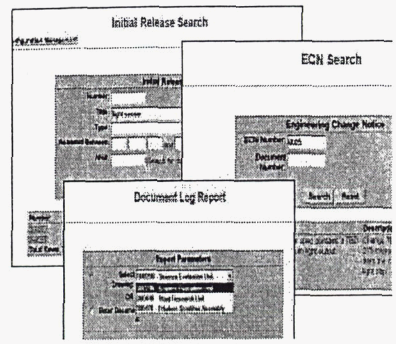
- Description
  - Provides personnel, resources, and budget analysis to Project Manager to assist him/her in daily decision making.
  - Maintains a database of trends, forecasts, and decision tree alternatives to support a flight project.
- Main responsibilities
  - Uses software tools such as Microsoft Excel, and Integrated Financial and Management tools to develop and monitor the trends, forecasts, and budget management pertaining to a project.
- Required Education
  - BSBA, MBA, BA, and related fields.
- Typical projects
  - All past and current flight missions including: EOS, FUSE, HST, Landsat, Swift, JWST, etc.
  - Assist Principal Investigators (PIs) and proposal engineers in submitting proposals in response to Announcements of Opportunity (AO) from NASA HQ and other federal agencies involved in space programs (e.g., DOE, Dept. of Commerce).



Typical project's budget.

Configuration Management

- Description
  - Assists PM and SE to ensure that all project specifications are traced from inception throughout launch and flight operations.
  - Maintains all documentation such as requirement documents, test plans and reports, engineering drawings, problem reports, as-build deviations, etc.
- Main responsibilities
  - Utilize software tools such as MS Excel and standard word editors (e.g., Word) to maintain and update the above documentation.
  - [OPTIONAL] Maintains Web Servers and interactive Web clients to expedite and facilitate document submission, approval, and archiving.
- Required Education
  - BS or BA in BA, management, CIS, engineering (all fields), mathematics, and other technical or financial related fields.
  - HTML/HTTP, CGI, Pearl, ActiveX, webserver installation, configuration, and maintenance very helpful.
  - *Webmaster experience* desirable.
- Typical projects
  - All past and current flight missions including: EOS, FUSE, HST, Landsat, Swift, JWST, etc.



Typical commercial Web client forms for CM.

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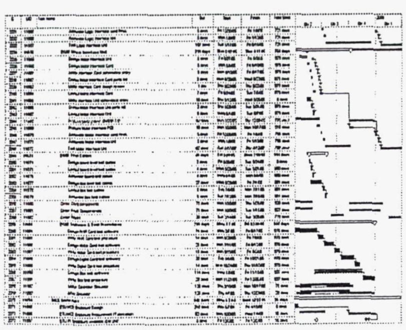
Planning & Scheduling

- Description
  - Provides personnel, resources, and schedule analysis to PM to assist him/her in daily decision making.
  - Maintains a database of personnel, resources, facilities, and deliverables to support the PM.
- Main responsibilities
  - Uses software tools such as Microsoft Project to monitor the project's schedule.
  - Advises the PM of critical path items.
  - Maintains PERT and Gantt charts
- Required Education
  - BSBA, MBA, BA, and related fields.
- Typical projects
  - All past and current flight missions including: EOS, FUSE, HST, Landsat, Swift, JWST, etc.
  - Support other center-wide activities such as building maintenance and improvement.
  - New building construction scheduling.



Typical project's Gantt Chart.

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Other Space Flight Engineering Disciplines

- Quality Assurance
- Reliability Analysis
- Parts Engineering
- Network Administration
- Compatibility Testing
- Manufacturing
- Materials Engineering
- Optomechanical Systems
- Microwaves & RF
- Nanotechnology
- Program Analyst
- Information Systems ...

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Conclusion

- Current Engineering Opportunities
  - In all of the above fields with emphasis on electrical, computer, aerospace, and mechanical engineering
- Engineering Paths
  - Mostly electrical, electronics, mechanical, materials, aerospace, and computer engineering
- Science Paths
  - Most likely physics, astrophysics, mathematics, materials, chemistry, computer science, astronomy, meteorology, optics, exobiology
- Administrative Paths
  - Accounting, business administration, public affairs, contracting, Computer Information Systems (CIS)
- Future Missions
  - Mission to the Moon, Mission to Mars, JWST, Gravity Wave Detection (LISA), Constellation X (X-ray spectroscopy), Life Finder and Planet Finder, Black Hole Imager, Stellar Imager (UV Interferometer Formation Flying), and much more ...

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Questions & Answers

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Acronyms & Definitions

Swift	***Gamma-Ray Burst Observatory***
BAT	Burst Alert Telescope
BATSE	Burst And Transient Source Experiment (CGRO)
BBOY	Brightest Burst of the Year
Block	2048 CZT detector subassembly
CCSDS	Consultative Committee for Space Data Systems
CZT	Cadmium-Zinc-Telluride semiconductor detector
DM	Detector Module
FWHM	*Full-width, half-maximum*
GRB	Gamma-Ray Burst
Hypernova	Explosion about 100 times more powerful than a supernova explosion, caused by the collapse of a very massive star (mass ≥ 40 Suns).
Neutron star	A very dense star with the mass of about 1.4 Suns within a 10 km sphere.
PSF	Point Spread Function
UVOT	Ultraviolet and Optical Telescope
XRT	X-Ray Telescope
JWST	**James Webb Space Telescope**
Big Bang	Start of the universal expansion---when all matter was clustered at the *beginning* and it *exploded*. This expansion continues --galaxies are still moving apart as measured by *redshift*.
Exobiology	The search for the origin of life on the Earth, and in the Universe.
EPU	Electrical Power Unit
FGS	Fine Guidance Sensor
FPA	Focal Plane Assembly
FPE	*Focal Plane Electronics*
HST	Hubble Space Telescope
IFU	Integral Field Unit
Interferometry	The applied science of combining two or more input points such as optical measurements to form a greater picture based on the combination of the two sources. In astronomy it combines light from two or more telescopes to obtain measurements with higher resolution.
IRSU	ISIM Remote Services Unit
ISIM	Integrated Science Instrument Module
MCE	*Microshutter Control Electronics*
MIRI	Mid Infrared Instrument (MIRI)
MSA	Microshutter Assembly
MSS	MicroShutter Subsystem
NIRCam	Near Infrared Camera
NIRSpec	Near Infrared Spectrometer
NGST	Next Generation Space Telescope (former name for JWST)
Redshift (z)	A stretching in wavelength of radiation. An example is the Doppler shift when a sound source is *moving relative to the listener. Galaxies are said to have a redshift of 1 if their spectral features* have shifted to twice as long a wavelength. If their features have shifted to 3 times the wavelength they have redshift 2. JWST will see redshifts of 15 to 30, where UV is redshifted into IR.
SSDIF	HST Space Systems Development and Integration (SSDIF) Facility